

Red Hill LNAPL Migration – Preliminary Assessment

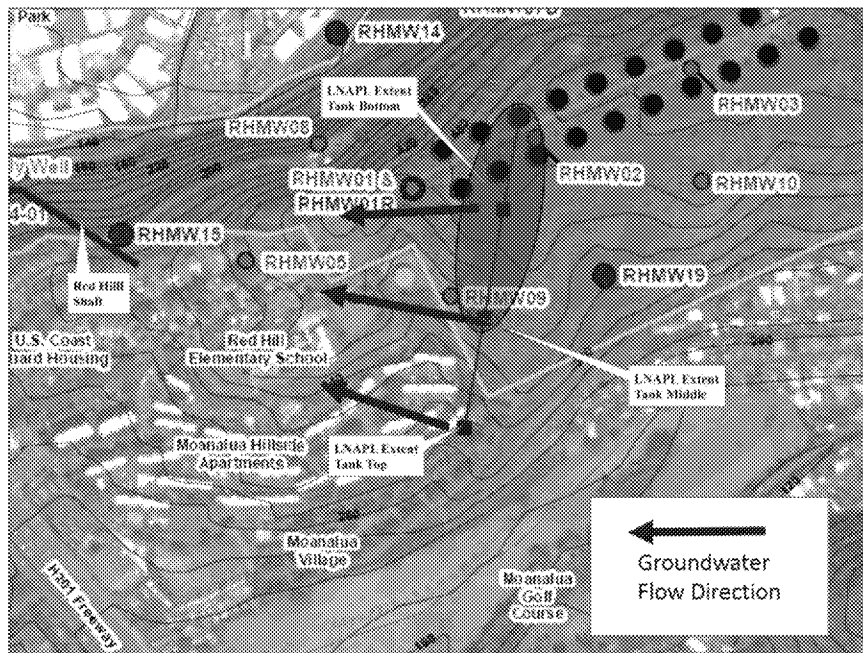


Figure 1. A map showing the probable LNAPL flow path based on lava bedding geometry

This represents a first pass assessment of the likely location where LNAPL from the January 20, 2014 would intercept the water table. This assessment compared the most likely location of the LNAPL footprint at the water table with the current well locations, and the chemistry from those wells. It is generally accepted that LNAPL migration would, under high rates of discharge, follow the plane of the lava bedding with downward drainage along that path; lower rates of discharge would be displaced to a lesser extent due to their ability to infiltrate through fractures in the lava bedding. If perching formations are present within the stratigraphic section, then even relatively low rates of discharge would be expected to follow this plane. Currently the best estimate of the lava bedding geometry is a dip of 13° along a bearing of 190°.

The figure above shows the results of this first-pass analysis. The line shows the trace from UST 5 to where a plane from the top of this tank would intersect the water table. The colored squares along the line show planes from the bottom, middle, and top of UST 5 would intersect the water table. Since the volume that could be released to the environment decreases the further one goes up vertically along

Commented [D1]: I would include an oval extending from immediately below the tank to that shown and specify that the distribution would be highly dependent on the magnitude/rate of release – smaller volumes/rates would be able to sink to the wt in a near vertical trajectory whereas a larger release would be distributed in a generally SSWesterly direction.

Commented [WR2R1]: Modified oval to include UST 5, thanks.

the tank, the span from the bottom to the middle of the tank is of most concern. The colored oval along the LNAPL trace represents the estimated foot print of the where the LNAPL would reach the water table from a leak interval from the bottom to the middle of the tank. The blue arrows show an assumed groundwater flow direction from the LNAPL trace to the Red Hell Shaft.

To date, no LNAPL has been detected. So the primary question is whether or not the current well locations would be expected to detect any LNAPL that may have reached the water table. Based on this assessment, RHMW01 and RHMW09 are the wells most likely to intersect any LNAPL or dissolved plume. The solid casing of RHMW01 extends beneath the water table so LNAPL can't be directly measured in that well. However, as Table 1 below shows, the TPH-d concentrations in RHMW01 (97 µg/L) and RHMW09 (<25 µg/L) are well below the solubility limit of jet fuel indicating LNAPL is not present. The TPH-d concentrations are also below the environmental action limit. However, due to the distance between RHMW01 and RHMW09 and the proximity to the mostly LNAPL location at the water table, these wells could miss the LNAPL. However, there is no evidence currently available to indicate that LNAPL has reached the water table along the most probable impact line.

The next step is to assess whether or not water impacted by fuel contamination has reached the water table along the probable LNAPL migration path. This can be done by observing chemistry for petroleum contaminants and for the concentrations of the natural attenuation parameters (NAP). The table below gives the chemistry for RHMW01, 02, 03, 04, 05, and RHMW09 as measured during the April, 2017 sampling round. RHMW03 and 04 are included as candidates for background NAP concentrations of sulfate and nitrate. Evidence of natural attenuation would be concentrations lower than background concentrations for these species. RHMW03 has the highest concentrations of the NAPs so would be a candidate for a background well. However, this well also has detectable TPH and the highest groundwater temperature of any well in the Red Hill Monitoring Network (RHMN). RHMW04 is most upslope of any well in the RHMN making it a candidate for designation as a background well. However, RHMW04 has NAP concentrations significantly lower than other wells in the RHMN (e.g. RHMW03 & RHMW05).

It is also important to note that the nitrate concentrations reported by the Navy appear to be unreasonably high. The nitrate concentration in Hawaii groundwater not affected by agriculture is usually less than 1 mg/L. Nitrate analysis for the RHMN for samples collected in previous years and from wells in the Moanalua and Halawa vicinity had nitrate concentrations much less than those currently being reported for the RHMN. Some of the nitrate concentrations measured in the April 2017 sampling round exceed the maximum measured by the USGS for all of southeast and central Oahu as part of the 2001 NAWQA study. The high nitrate wells for the USGS NAWQA study were located in fields where sugar cane formerly was grown and it is expected that the nitrate concentration in those wells would be elevated. Nearly all of the other wells had nitrate concentrations of 1 mg/L or less.

Chloride is also included in Table 1 for two reasons. Chloride is recognized as natural groundwater tracer and significant differences in the chloride concentrations in these wells would lessen the confidence in hydraulic connectivity between the contrasting wells. The second is that one of the major sources of sulfate is seawater aerosols precipitated with atmospheric moisture. The seawater SO₄: Cl ratio is 0.14. A deviation from this ratio would indicated another source of sulfate, or alteration/chemical reaction of sulfate such as occurs during natural attenuation of fuel hydrocarbons.

Commented [D3]: Does this well still show TPH? If so it would be interesting for their forensic chemist to look at the GC traces to determine whether it is related to the recent spill or an older one...

Commented [WR4R3]: Yes, that can be done by GSI's forensic chemist, or we could also do a first pass assessment by looking at the chromatographs and the results of the silica gel cleanup analysis.

A question that remains unanswered is what SO₄:Cl to use when evaluating whether or not natural attenuation has occurred: 0.14, the seawater ratio; or 1.03, the ratio at RHMW03.

A review of the chemistry is inconclusive as to whether or not the groundwater along the estimated LNAPL/infiltration leaching flow path shows an impact for the 2014 release. The TPH concentrations at RHMW01 after the 2014 release are similar to those prior to the release. RHMW09 is interesting because the SO₄:Cl ratio is 0.19. This is elevated compared to seawater ratio, but depleted compared to the RHMW03 ratio. Also, the SO₄:Cl ratio at RHMW04 is 0.13, slightly depleted compared to seawater and heavily depleted compared to RHMW03. It is also interesting to note that the temperature in RHMW09 varies from about 23 to 24° C. There is a similar pattern for nitrate in these two wells compared to other wells in RHMN that are not affected by natural attenuation. RHMW05 shows elevated nitrate, sulfate, chloride, and SO₄:Cl. The chloride concentration that is three times that of the upslope wells brings into question the degree of hydraulic connectivity along the RHMW03, 02, 01, & 05 line. The chloride concentration at RHMW09 is similar to that at RHMW01&02. However, this does not definitely show good hydraulic connectivity. A groundwater temperature, based on a survey of wells in the Honolulu Aquifer, would be expected to be in the 21 to 22° C temperature range. Since natural attenuation chemical reactions are exothermic, this may be an indicator of natural attenuation occurring in the vicinity of RHMW09. The nitrate and sulfate isotopic analysis may shed light on what wells show influence of natural attenuation.

What does this mean for the Red Hill Groundwater Risk Investigation? First there is no strong evidence that LNAPL from the 2014 release reached the water table. There are wells located near the estimated most probable footprint of where the LNAPL would reach the water table. None of these wells show evidence of LNAPL. Whether or not the water in these wells shows alteration by fuel contamination is less clear. RHMW09 shows concentrations of nitrate and sulfate compared to RHMW03, but are approximately equal to RHMW04. Thus to adequately evaluate the spatial impact of the current and past releases at Red Hill the representative background concentrations of the NAPs must be defined. If the currently estimated plane of the lava bedding is representative of the Red Hill Ridge, more monitoring wells need to be installed along the southeast side of the USTs to be able to monitor contamination in the most likely areas where fuel releases would impact the groundwater.

Table 1. A Summary of TPH and NAP Chemistry in Background Wells and Wells along the estimated LNAPL Migration Path

Well	TPH-d	SO4	NO3	Cl	SO4:Cl	Comments
RHMW04	<25	11	2.7	83.6	0.13	Possible background well for evaluation natural attenuation since it is the most upslope of the wells
RHMW03	47	48.9	7.2	47.3	1.03	Possible background well for evaluation natural attenuation based on the high NAP concentrations
RHMW02	<25	1.1	<0.18	39.9	0.03	
RHMW01	97	5	<0.18	40.1	0.12	
RHMW05	<25	44.1	4.5	148	0.30	
RHMW09	<25	9.9	2.5	52.3	0.19	
All units except the SO4:Cl are mg/L						

Some Other Thoughts

1. AECOM strongly implied that the Quarry is degrading water quality to the point that a mile away the chloride concentration is over 4 times the secondary SMCL at OWDF MW1. Also, the chloride concentration at RHMW06 & 07 are above the SMCL.
 - a. The high chlorides are measured more than a mile from the quarry so if AECOM's assertions are true the quarry operations are significantly degrading the quality of the drinking water beneath their operations
2. AECOM and GSI consistently state that there is very little recharge through the Red Hill Ridge due to the saprolite cap.
 - a. The tests in the work plan to date are insufficient to demonstrate this. It will take more than an infiltration test to demonstrate this
3. For well over a year AECOM and more recently GSI have consistently stated that focused recharge at the quarry creates a groundwater mound.
 - a. Since it appears that no well will be installed in the quarry there is nothing in the work plan to validate this contention – until data can validate that contention, it shouldn't be used in the model,
 - b. The only evidence to date is conjecture and anecdotal evidence observed only by AECOM.
 - c. Proof of concept testing could easily be done by running scenarios on the current model.
 - d. We should arrange a tour of the Quarry Facilities to field check AECOM's assertions

Commented [D5]: Which well was this?

Commented [D6]: Existing recharge models indicate that rainfall over the Red Hill ridge is a trivial fraction of the total recharge into this area and, hence, there is very little influence from recharge over the regional groundwater flow rates and directions. Hence, the infiltrometer data is at best irrelevant whether the saprolite cap is affecting the infiltration or not.

4. AECOM/GSI does a poor job of vetting what they are going say:
 - a. The piper diagram, while the plotting of data was done correctly, was misinterpreted badly. This should have been caught by an internal review process
 - b. Implicating the quarry in causing wide spread degradation of a drinking water aquifer is a very serious charge. Something like this should have never made it into a presentation to the regulators unless there is solid evidence to back it up.